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Medical Image Segmentation Based on Morphology Algorithm and FCM Algorithm

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Abstract

Fuzzy c-means algorithm is an unsupervised clustering algorithm, its clustering process can reduce the human intervention, and it is suitable for processing medical images of uncertainty and ambiguity. When simply using FCM algorithm in brain image segmentation will leads to the condition of low accuracy. On the basis of FCM algorithm, this paper proposes a new method which combines FCM algorithm and morphology algorithm. The result of simulation shows that this method can accurately and efficiently segment the brain image. The new algorithm is an effective method for image segmentation.

Keywords: *FCM algorithm; Morphology algorithm; Image segmentation; Medical image*

1. Introduction

In recent years, with the rapid development of medical images, this phenomenon makes that medical diagnosis is increasingly inseparable from medical imaging technology. Medical image segmentation has become a hot issue in the field of image processing. Medical image segmentation first extracts features of the object, then divide the image into disjoint tissues or organs, analysis the organization qualitatively and quantitatively. Image segmentation is the basis for image recognition and image analysis, the results of segmentation will determine the function of subsequent image analysis and image recognition [1].

The basic idea of the image segmentation of morphology algorithm is to subtract the original image after the basic operation with some structural elements; it makes operation by using the topological characteristics of the image, and use set theory for nonlinear image transformation [2]. In addition, morphology algorithm is easy for parallel processing and easily implemented in hardware.

Based on fuzzy sets to deal with clustering problem is first proposed by Bellan, Kalaba and Zadeh in 1966. Fuzzy c-means algorithm is applied in the field of pattern recognition as an unsupervised fuzzy clustering calibration process, commonly used in medical image segmentation [3].

In this paper, the image used in the experiment comes from Brain Web. By using software Matlab to study the brain image segmentation, fuzzy c-means algorithm and morphological open operation and close operation are used for image segmentation. The simulation results show that this method can not only segment the brain image effectively, but also can reduce the number of iterations and the time of FCM algorithm. The new method is effective for image segmentation, especially for noisy image.

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2. The Basic Principle and Method

2.1. The Basic Principle of Morphology Algorithm

Morphology is a nonlinear theory of image processing and analysis, morphology can be considered as a unified theory of image processing, it abandons the traditional way of mathematical modeling and analysis, but processes and analyses the image in view of the collection [4]. It is a mathematical method used to study the geometry and structure, so it can use unified and powerful image processing tools to solve problems encountered.

The basic operations of mathematical morphology algorithm are defined for binary images, but in fact the brain images are gray-scale images. Although it is possible to select an appropriate threshold to convert gray-scale image into binary image, then process the image by using the corresponding algorithm, but this kind of transformation is bound to lose some useful image information. Therefore, this paper processes the gray-scale image using morphology algorithm directly.

During the process of gray-scale image, the input and output of the image are in the form of gray level, which means that the input and output pixel values is between the minimum gray value and the highest gray value [5]. Set f is the input image, b is a structural element, using structure element b on expansion of the image f is defined as:

$$(f \oplus b)(s,t) = \max\{f(s-x,t-y)+b(x,y) \mid (s-x),(t-y) \in D_f \ \& \ (x,y) \in D_b\} \tag{1}$$

In Formula 1, D_f is the domain of f and D_b is the domain of b.

f expanded by b is defined as:

$$(f \Theta b)(s,t) = \min\{f(s+x,t+y)-b(x,y) \mid (s+x),(t+y) \in D_f \ \& \ (x,y) \in D_b\} \tag{2}$$

In Formula 2, D_f is the domain of f and D_b is the domain of b.

On the basis of the expansion and corrosion, there appear two other new algorithms: open operation and close operation. The open operation is defined as $f \circ b$, it is first to corrode and then inflate:

$$f \circ b = (f \Theta b) \oplus b \tag{3}$$

The close operation is defined as $f \bullet b$, it is first to inflate and then corrode:

$$f \bullet b = (f \oplus b) \Theta b \tag{4}$$

2.2. The Basic Principle of FCM Algorithm

FCM algorithm is a new algorithm based on improved K-means algorithm, proposed by Bezdek (1981). It is to divide the input vector into different categories by using the fuzzy method, through continuous iteration, finally obtain the optimal result of clustering. The objective function can be expressed as follows [6]:

$$J_m(U,P) = \sum_{k=1}^{n} \sum_{i=1}^{c} (\mu_{ik})^m (d_{ik})^2, m \in [1,\infty) \tag{5}$$

Data set $X(x_1, x_2, x_3 ..... x_n)$ represents an image having N pixels, it is divided into class C. x represents the pixel in the image. m represents weighted index, also known as the smoothing parameter [7]. μ_{ik} represents the membership function that is x_k in any of the samples X belonging to the cluster i, $d_{ik} = \| x_k - v_i \|^2$ is the distance between the pixel k and the clustering center i, Euclidean distance is used here.

The extreme constraints for formula are as follows:

$$\sum_{i=1}^{c} \mu_{ik} = 1 \tag{6}$$

$$\mu_{ik} \in [0,1] \tag{7}$$

$$0 < \sum_{k=1}^{n} \mu_{ik} < n \tag{8}$$

According to the Lagrange multiplier method, we can draw the necessary conditions for the extreme value formula:

$$\mu_{ik} = \frac{1}{\sum_{j=1}^{c} [\frac{d_{ik}}{d_{ik}}]^{\frac{2}{m-1}}}, k = 1,2,3.....N \tag{9}$$

$$v_i = \frac{1}{\sum_{k=1}^{n} (\mu_{ik})^m} \sum_{k=1}^{n} (\mu_{ik})^m x_k, i = 1,2,3.....c \tag{10}$$

When data sets *X*, the number of clustering center c and ambiguity parameter m are under known circumstances, according to the equation, the problem can be solved by an iterative method.

2.3. Implementation Steps of the Algorithm

Step 1: Pre-process the original image.

Step 2: Process the image by using gray morphology algorithm.

Step 3: Calculate or update the membership matrix U according to the formula (9).

Step 4: Update the cluster centers V by the formula (10).

Step 5: If $\| v^i - v^{i+1} \| < \xi$, then the algorithm stops, output segmentation results. Otherwise, make $i = i + 1$, turn to the Step 3.

3. Image Processing by Morphology Algorithm

FCM algorithm can segment the brain image. However, the brain image is vague and the accuracy of segmentation is not that high. The experimental data is the real brain MRI image, the image is fuzzy because of the complexity of structure of the body, and the image is inevitably affected by noise during the form of processing. Gray-scale morphology algorithm is simple and efficient; it can filter out the noise and reduce the effects of noise on the image segmentation. So this paper presents a method combining morphology algorithm with fuzzy c-means algorithm for image segmentation. The new algorithm can improve the accuracy of segmentation.

Brain MRI images are inevitably affected by the interference of noise and impact in the process of uptake and transport. So before image segmentation, noise removal is one of our tasks. Because open operator can remove smaller brighter details, close operation can remove smaller dark details [8], Open operation and close operation can be used to extract image features and smooth the image. The quality of gray-scale morphology processing depends on the shape and size of structure element, this paper adopts the radius of 1 round structure element to segment the image, Figure 1 is the original image, the result in Figure 2, is processed by the open and close operation.

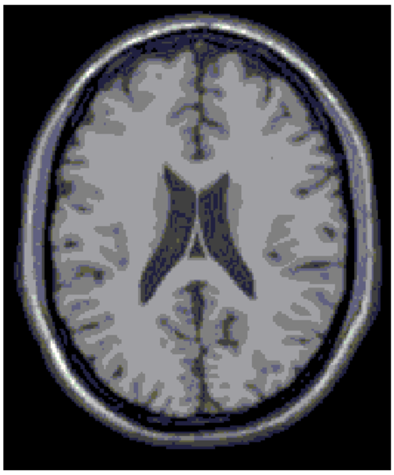

Figure 1. Original Image

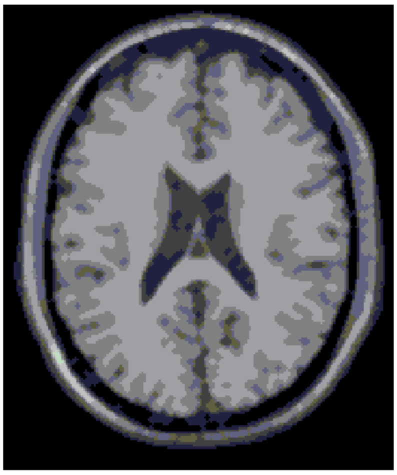

Figure 2. Original Image After Processing

4. The Experimental Results and Analysis

This article is based on the brain MRI image, image's size is 181×217. The simulation environment is based on Matlab [9]. The test platform is Intel Core i5, 3230 M, CPU clocked at 2.6 GHz, 4GB of memory.

4.1. The Original Image Segmentation

At present, the theory of parameters in the FCM algorithm is not accurate, for the most, it is obtained in the experiment. We find that the cluster center C and ambiguity parameter m also can make influence on the results in the experiment. According to the gray histogram of the image, there are four peaks in Figure 3. After many experiments, we can conclude that when the clustering center C=4 will get good results. When the formula $m=1$ is true, then the fuzzy c-means algorithm degenerates into hard-means algorithm, when m is too large will cause fuzziness segmented image. Pal etc. [10] has found that m best interval is [1.5, 2.5] after many experiments, this paper takes $m=2$.

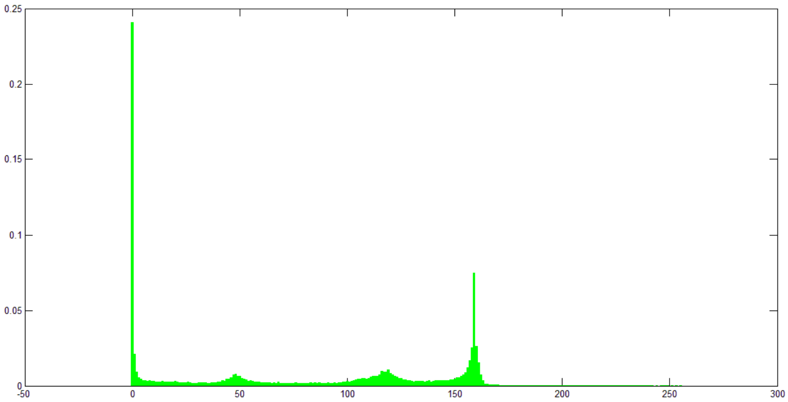

Figure 3. Gray Histogram

During the experiment, the fuzzy c-means algorithm and the improved fuzzy c-means algorithm are adopted to segment the image. In the process of segmentation, with the increase of the number of iteration, there exit different objective function values. As shown in Figure 4, and Figure 5, Figure 4, is the result of the fuzzy c-means algorithm iteration; Figure 5, is the result of a combination of morphological open and close operation with the fuzzy c-means algorithm iteration. Results of the analysis are shown in Table 1, the iteration count of FCM algorithm is 95 and the function value is 12470567.109384, the iteration count of improved algorithm is 71 and the function value is 10821920.895345. As can be seen form the result, the improved algorithm's number of iterations is smaller, and gets a smaller objective function value too.

Table 1. Iteration Count and Objective Function Value

Algorithm	Iteration Count	Function Value
FCM Algorithm	95	12470567.109384
Improved Algorithm	71	10821920.895345

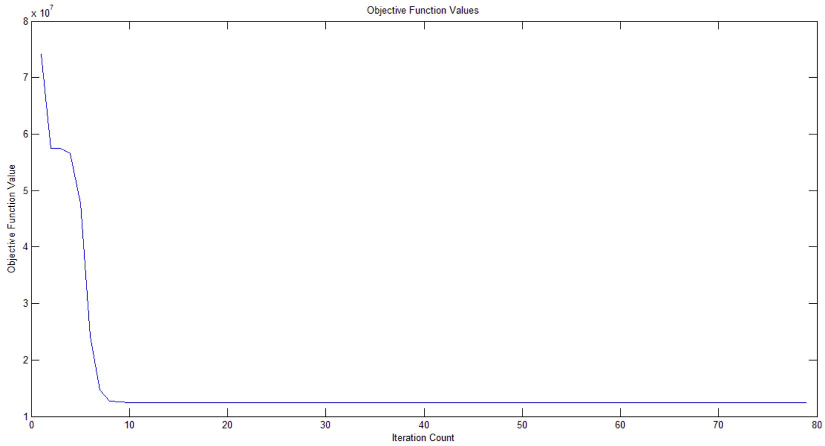

Figure 4. Iteration Count and Objective Function Values of FCM Algorithm

Figure 6, is the image segmented by FCM algorithm and Figure 7, is the image segmented by the improved algorithm. Because medical images are fuzzy and uncertain and it will be affected by the noise and other factors during the process of imaging. In addition, the FCM algorithm also extremely sensitive to noise, so the image appears inside unevenly divided, and there exit wrong points. Morphological open operation and close operation can smooth the image, so that the divided region is relatively uniform, it can improve the quality of the segmented image. In terms of computing time, fuzzy c-means algorithm for computing time is 3.509 seconds; the improved fuzzy c-means algorithm for computing time is 2.4705 seconds. Above all, the effect of improved algorithm segmentation is better than the traditional fuzzy c-means algorithm.

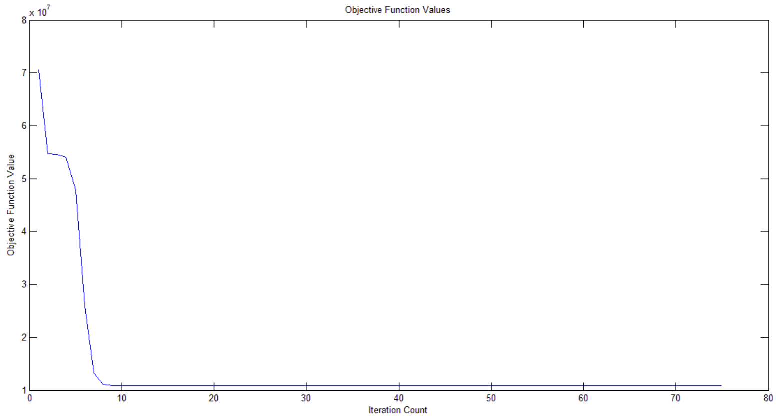

Figure 5. Iteration Count and Objective Function Values of FCM Algorithm and Morphology

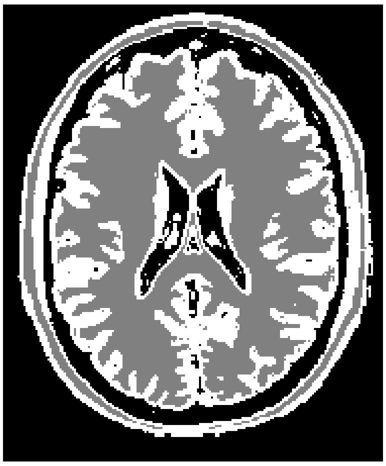

Figure 6. Result of FCM

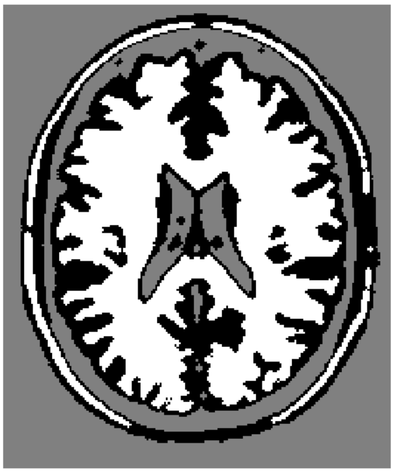

Figure 7. Result of Improved Algorithm

4.2. The Noisy Image Segmentation

In this paper, the main improvement is the aspect that fuzzy c-means algorithm is sensitive to noise. So the noise is added in the original image. Gaussian noise superimposed on the original image is to verify the proposed method’s robust to noise. The mean value of Gaussian noise is 0; the variance of Gaussian noise is 0.01. The results are as follows:

Figure 8, is the image polluted by Gaussian noise. As can be seen form it, the original image becomes fuzzier and the various parts of the brain image are more difficult to distinguish. Figure 9, is an image processed by the morphology algorithm, the noise is basically filtered out, compared with the Figure 3, (gray histogram of original image), and the gray value of the image increases; the original peaks and troughs are annihilated. Figure 11, is the gray histogram of the noisy image processed by morphology algorithm, as can be seen form it, the noise in image is filtered out, as can be seen form the Figure 11, compared with the Figure 10, Morphology algorithm can smooth the image.

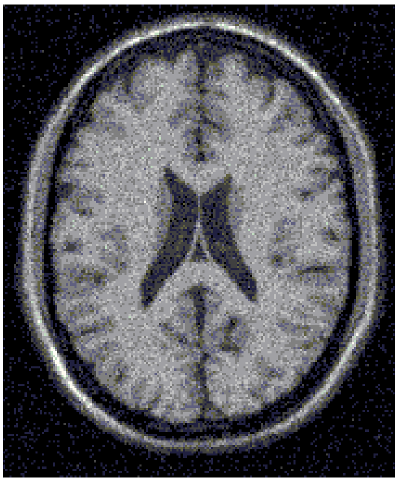

Figure 8. Noisy Image

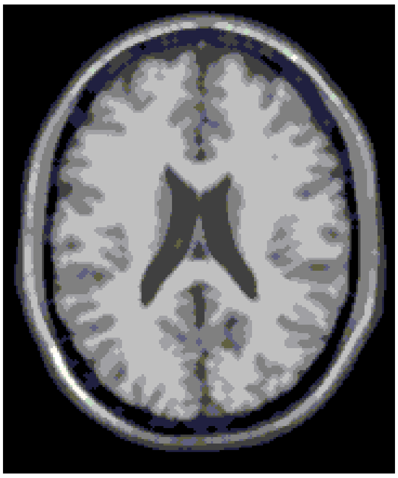

Figure 9. Processing Result

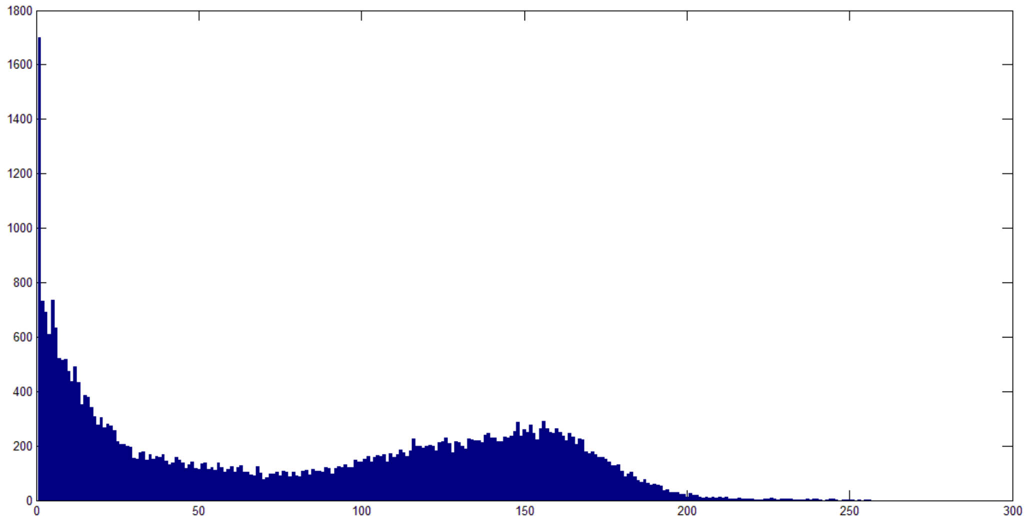

Figure 10. Gray Histogram of Noisy Image

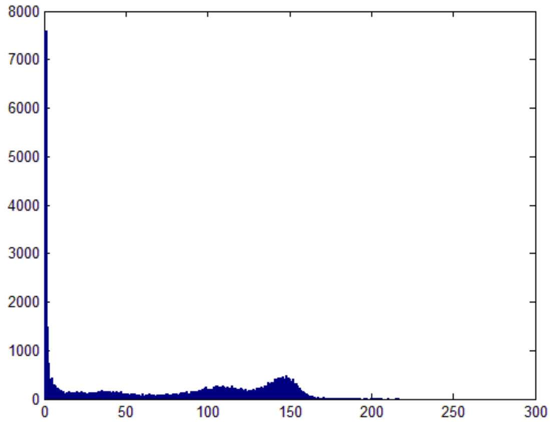

Figure 11. Gray Histogram of Processing Result

Figure 12, is the relationship between iterations and the objective function when only the fuzzy c-means algorithm is used. Figure 13, is the relationship between iterations and the objective function when the improved algorithm is used. As shown in Table 2, when the algorithm is under operation, the number of iteration of FCM algorithm is 52 and objective function value is 13780627.737117. The number of iteration of the improved algorithm is 50 and objective function value is 9610200.668708.

Table 2. Iteration Count and Objective Function Values of Noisy Image

Algorithm	Iteration Count	Function Values
FCM Algorithm	52	13780627.737117
Improved FCM Algorithm	50	9610200.668708

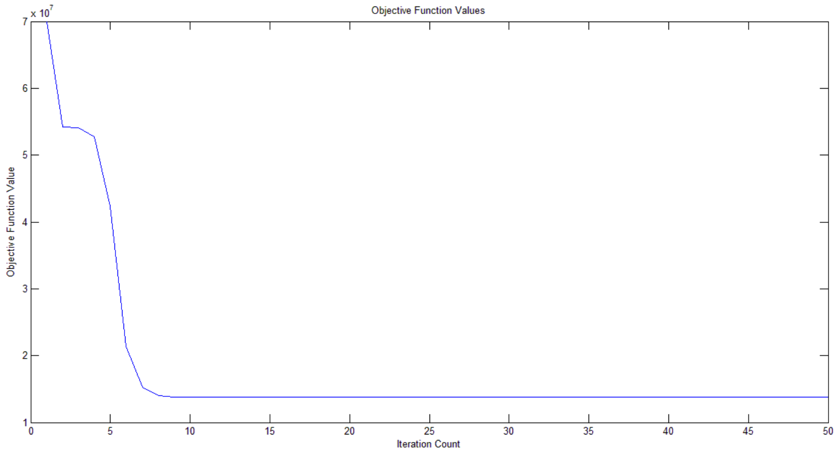

Figure 12. FCM Algorithm Iteration Count and Objective Function Values of Noisy Image

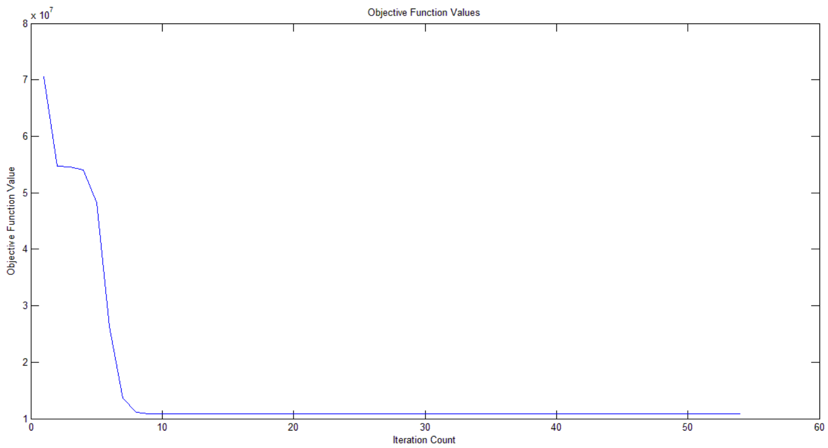

Figure 13. FCM Algorithm and Morphology Iteration Count and Objective Function Values of Noisy Image

As can be seen from the results, Figure 14, is the image adding noise segmented by the standard fuzzy c-means algorithm, it is can be seen that the result of image segmentation is not very good. Fuzzy c-means algorithm is sensitive to noise. Figure 15, is an image segmented by the new algorithm which combine the morphology algorithm and fuzzy c-means algorithm. The result is clear, there is no noise pollution, and the image is well segmented.

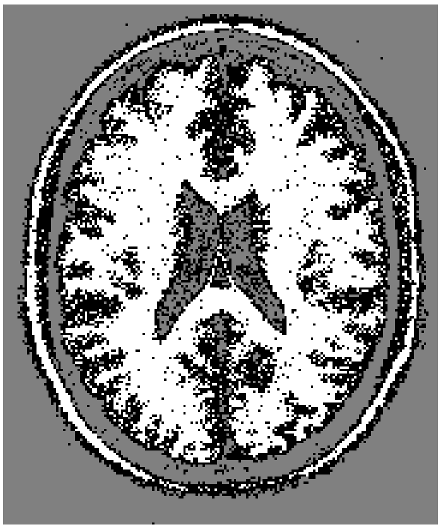

Figure 14. FCM Result

Figure 15. Improved Algorithm Result

As can be seen from the above, the improved algorithm when used in the standard image or the image polluted uses shorter time, less iterations and better segmentation results than standard fuzzy c-means algorithm, especially for the image affected by noise, the robustness of the improved algorithm is more good.

4. Conclusion

This paper deeply study the image segmentation method based on fuzzy c-means algorithm, proposes a new image segmentation method which combines morphology with the fuzzy c-means algorithm, and apply the new method into the brain image segmentation.

The accuracy of the segmentation is not high when only use the basic FCM algorithm in dealing with fuzzy brain image segmentation. In this paper, the integrated application of morphology algorithm and fuzzy C-means algorithm solve the problem effectively. When the algorithm is under operation, the number of iteration of FCM algorithm is 95 and objective function value is 12470567.109384. The number of iteration of the improved algorithm is 71 and objective function value is 10821920.895345.

The running time of FCM algorithm is 3.509 seconds, the running time of the improved algorithm is 2.4705 seconds. The new algorithm improves the efficiency of operation and the quality of segmentation. Seen from the simulation results, the brain image can be better split up. As we can seen form the two experiments, the robustness to noise of the improved algorithm increases greatly.

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